The Relative Role of Local and Regional-Scale Processes on Ozone in Philadelphia
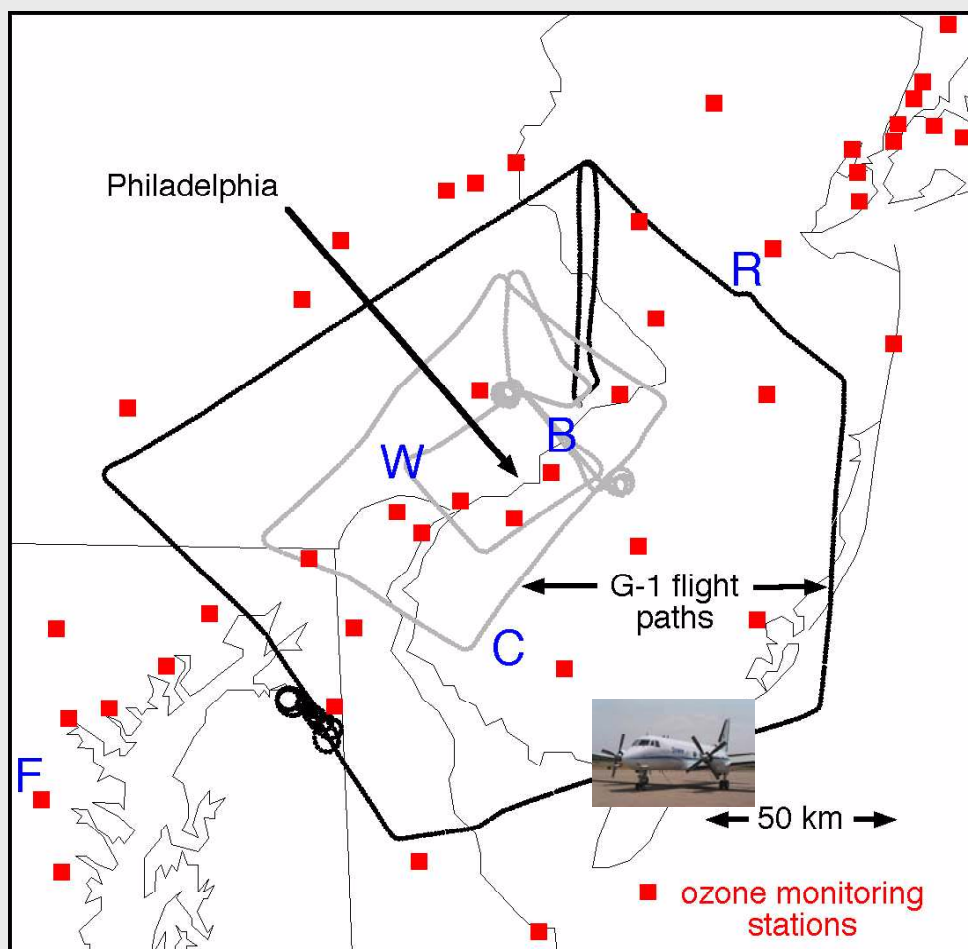
Jerome Fast

Pacific Northwest National Laboratory

with contributions from:

modeling: **Xindi Bian, Carl Berkowitz, Elaine Chapman, Richard Easter, Rahul Zaveri**

measurements: **Jerry Allwine, Chris Doran, Will Shaw, G-1 flight crew, ANL, BNL, and other NE-OPS participants**

1999 NE-OPS Field Campaign

Philadelphia

R

B

W

C

F

G-1 flight paths

50 km

ozone monitoring stations

http://www.pnl.gov/atmos.sciences/philadelphia_ex.html

- **wind profilers, B, C** (ANL), **W** (PNNL), **R, F**
- **sodar: C** (ANL)
- **radiosondes: B** (ANL), **C** (PNNL)
- **ozonesondes: B** (PNNL)
- **surface chemistry: B, C** (ANL)
- **tethersonde: B**
- **Raman lidar: B**
- **G-1 aircraft:** (BNL)

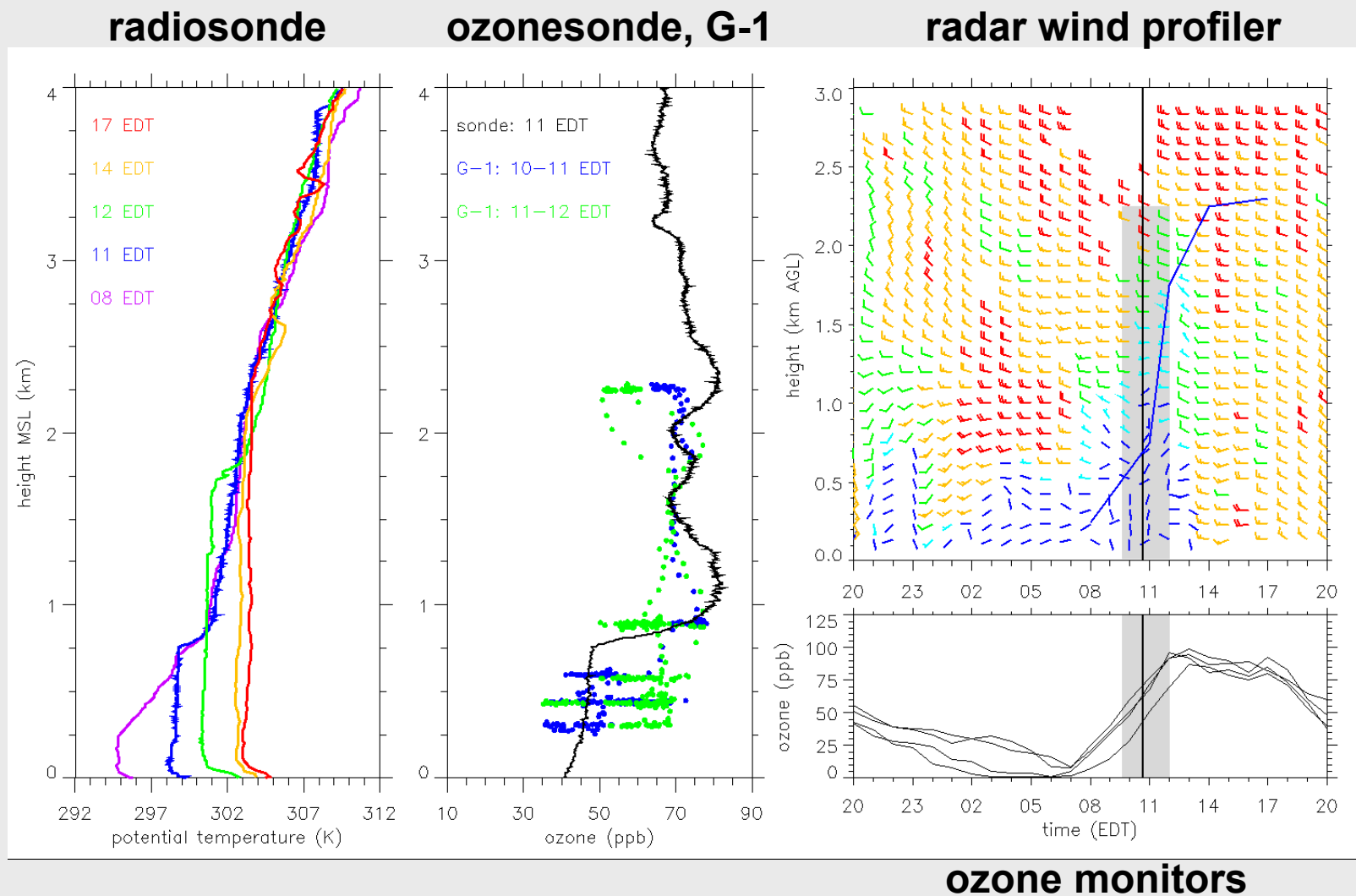**DOE Atmospheric Chemistry Program**

ANL   - Argonne National Lab.

PNNL - Pacific Northwest National Lab.

BNL   - Brookhaven National Lab.

Motivation: 5 August Observations

radiosonde **ozonesonde, G-1** **radar wind profiler**

ozone monitors

Model Description: PEGASUS

**mesoscale meteorological model (RAMS)**

- **nested configuration: 48, 24, 8, and 4 km grids, Δz_{sfc} = 25 m**
- **30-day simulation period: 12 UTC 15 July - 12 UTC 14 August**
- **4DDA on large-scale analyses**
- **clouds: form in areas of supersaturation**

chemical transport model

- **meteorological fields from RAMS, one-way coupling**
- **transport, vertical diffusion, chemical production/destruction, dry deposition, emission terms**
- **CBM-Z mechanism: 53 species and 133 reactions**
- **RODAS integrator**
- **photolysis rates modified by cloudiness**
- **day-specific emission rates on 8 levels from SMOKE (Jeff Vukovich, MCNC)**
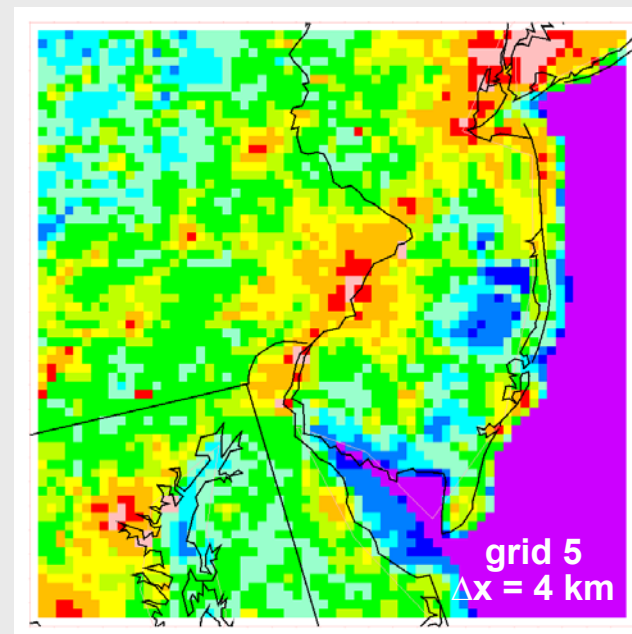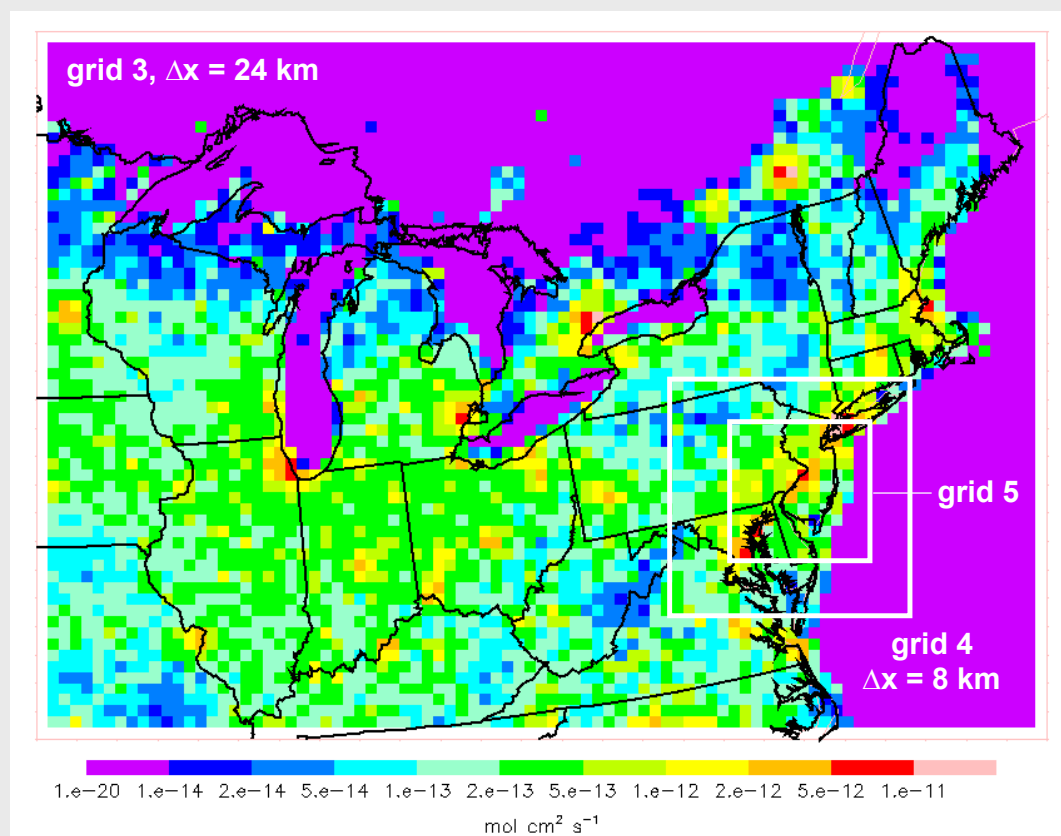
Data during Simulation Period
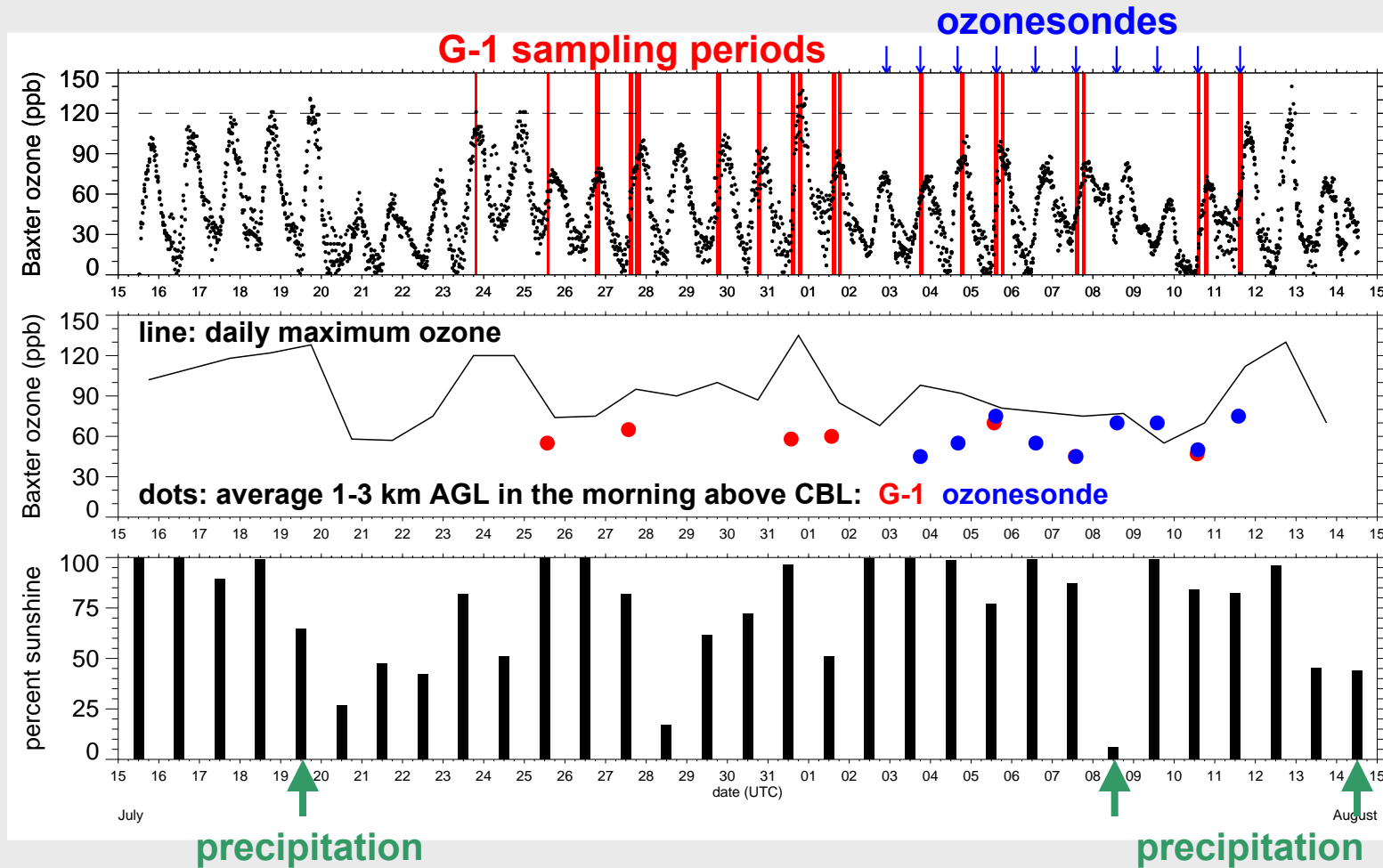
trend in maximum surface ozone not correlated with limited data aloft

Model Domains

Surface NOx Emission Rates, 12 UTC 15 July

(emissions aggregated from 4-km dataset)

Modeling Strategy

```
┌─────────────────────────────┐
│     "Control" Simulation     │
└─────────────────────────────┘
              │
              ▼
Evaluate simulated meteorological and trace gas fields using
          surface and upper-air observations
              │
              ▼
Qualitative assessment of regional-scale transport
              │
              ▼
┌─────────────────────────────┐
│   "Sensitivity" Simulations  │
└─────────────────────────────┘
              │
              ▼
Quantitatively determine relative role of local and regional
                     processes
```
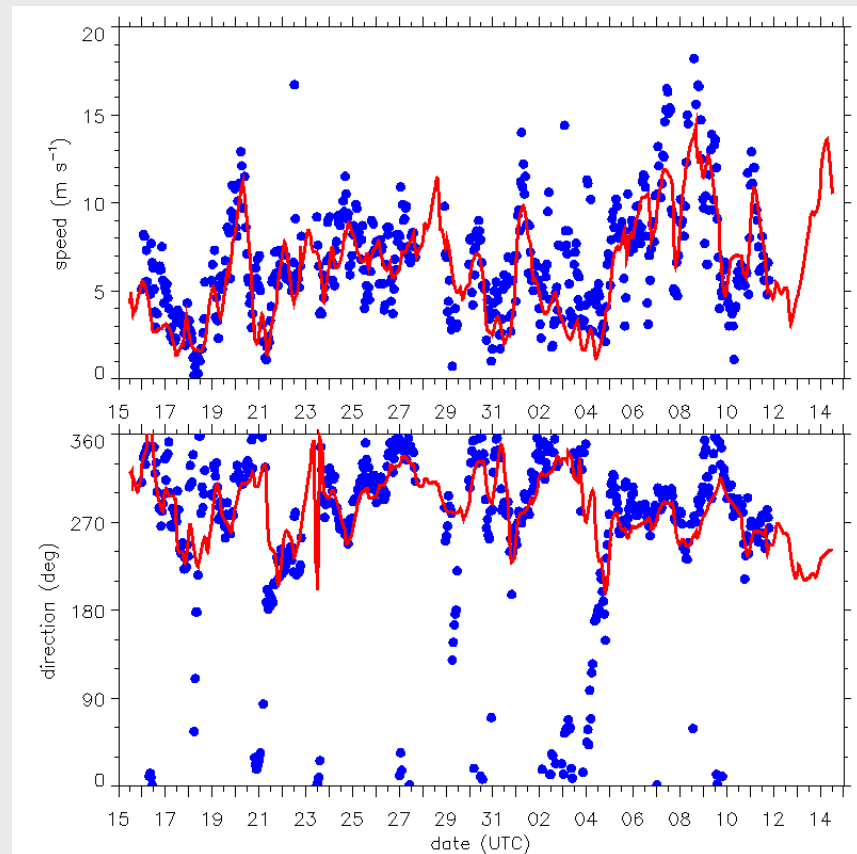
Evaluation: Upper-Air Winds

**mean and standard deviation
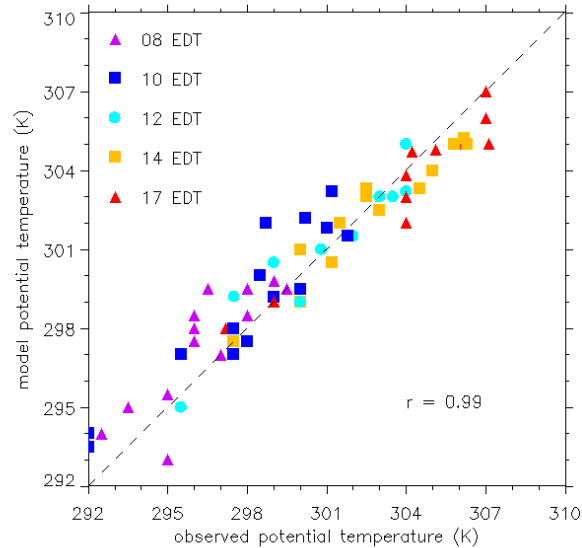of the bias (simulated - observed)**
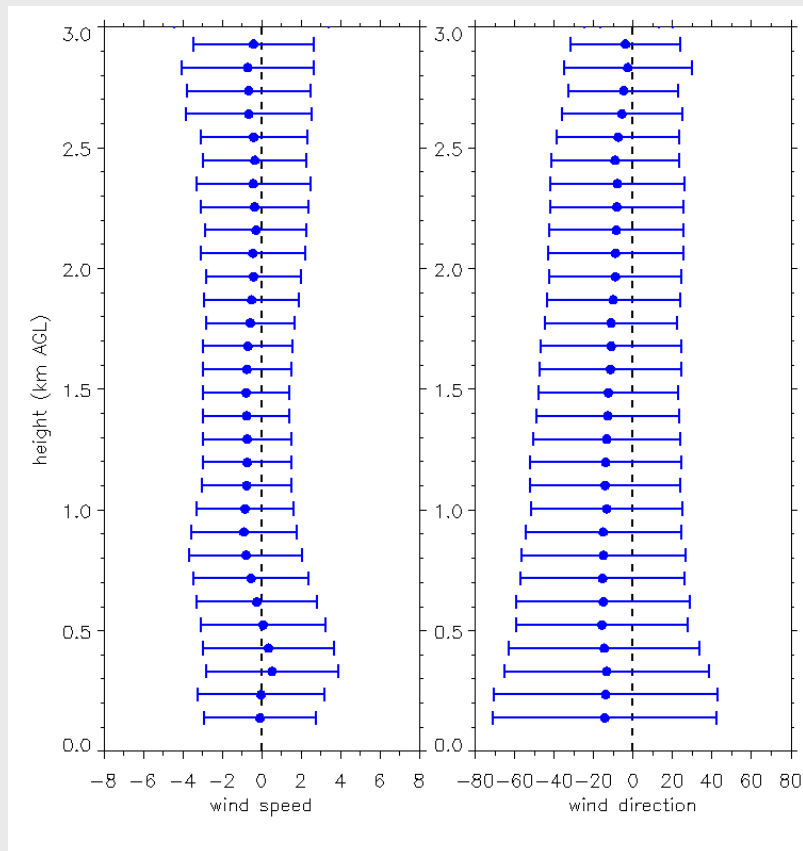
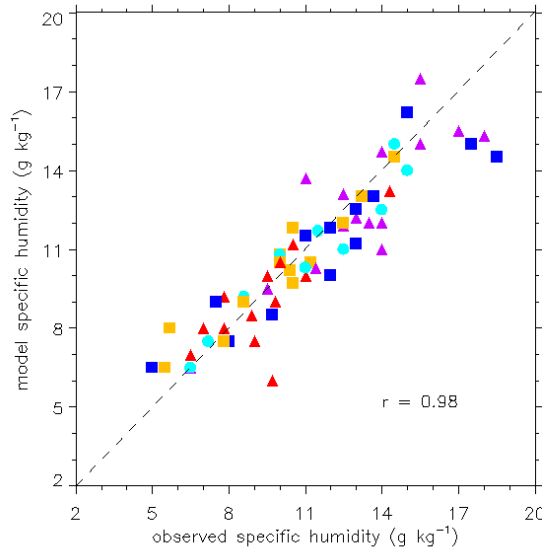**observed and simulated
~ 1.5 km AGL**

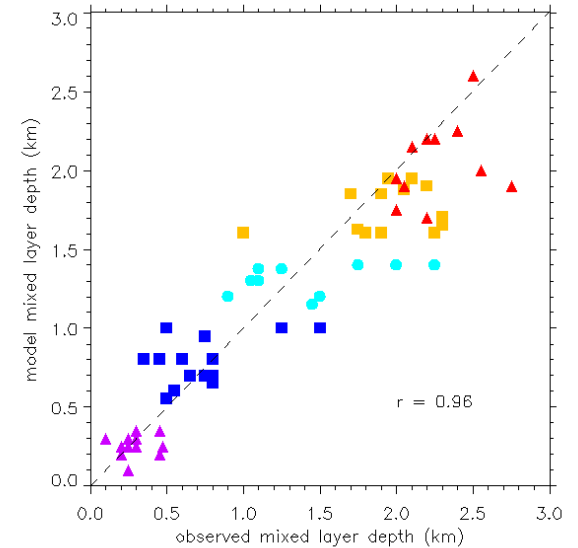# Evaluation: B-L Properties

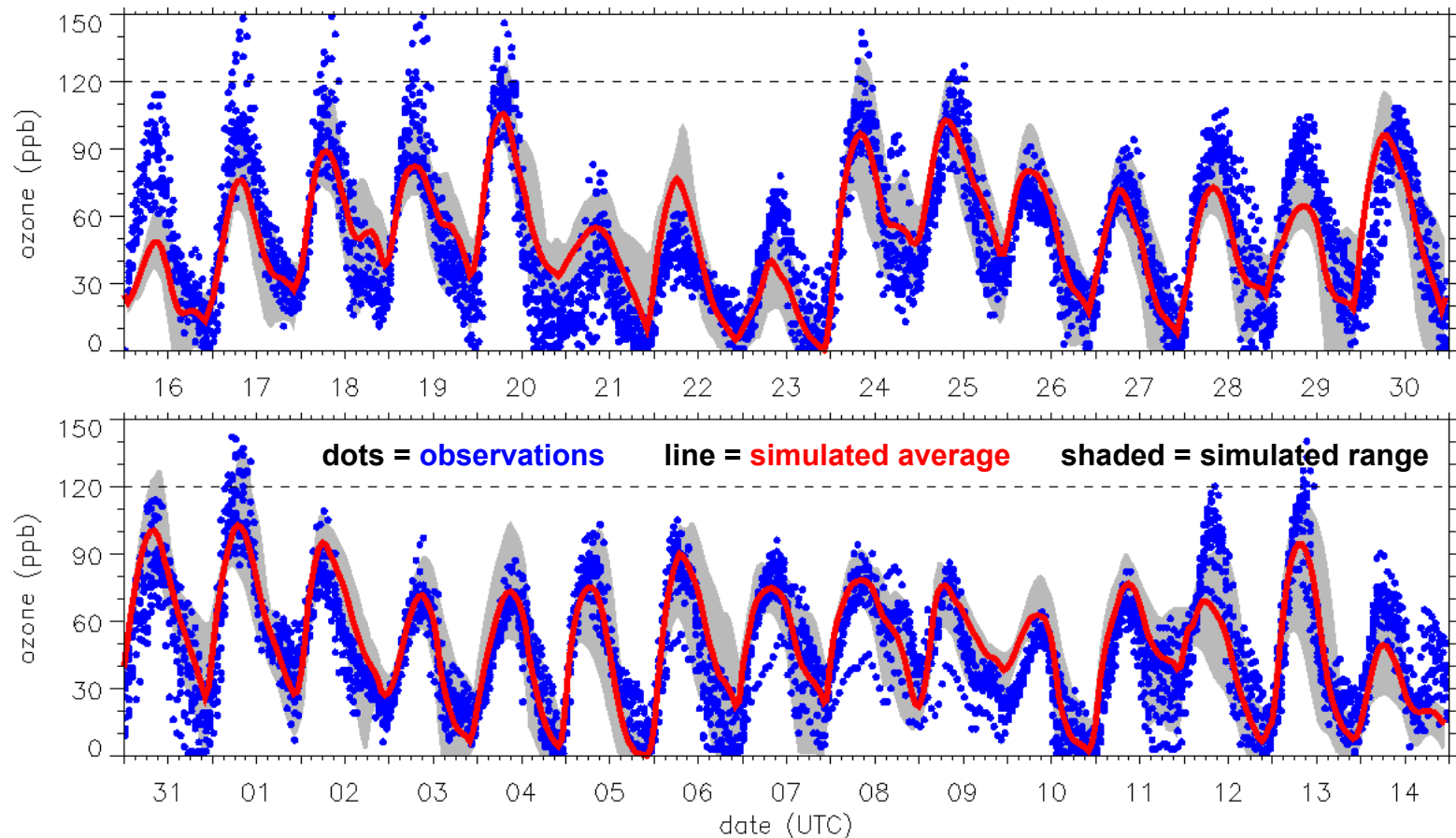**potential temperature** **specific humidity** **mixed layer depth**

**observed values based on 65 radiosondes from site B
between 23 July and 11 August**

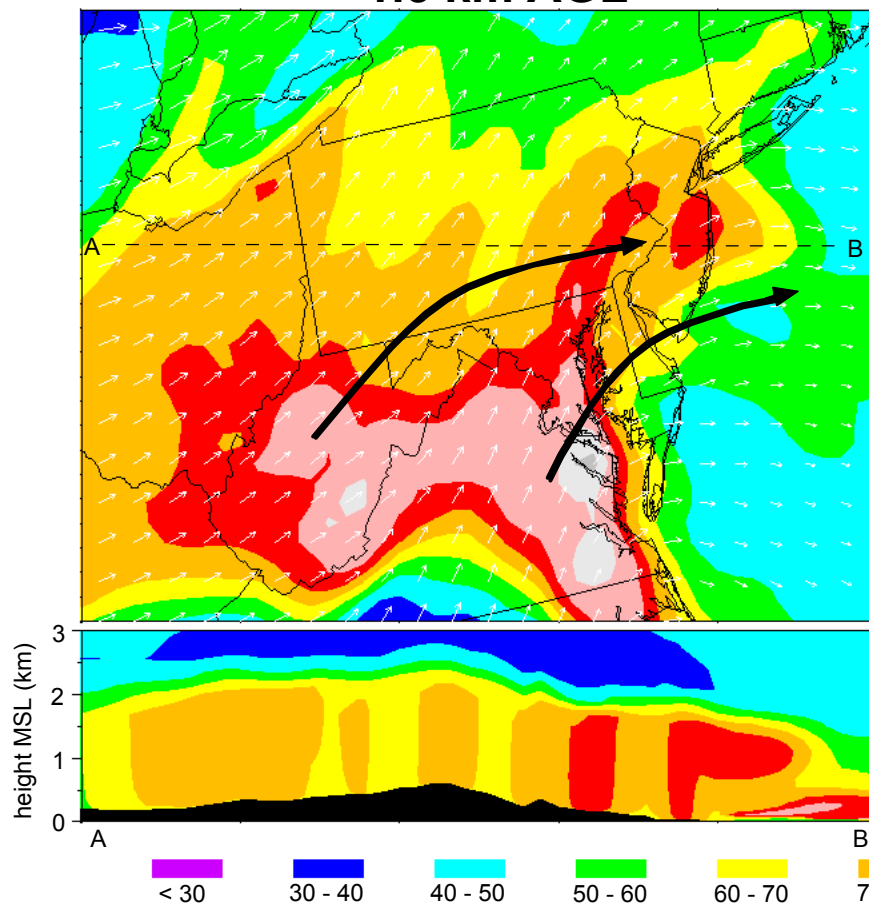# Evaluation: Surface Ozone

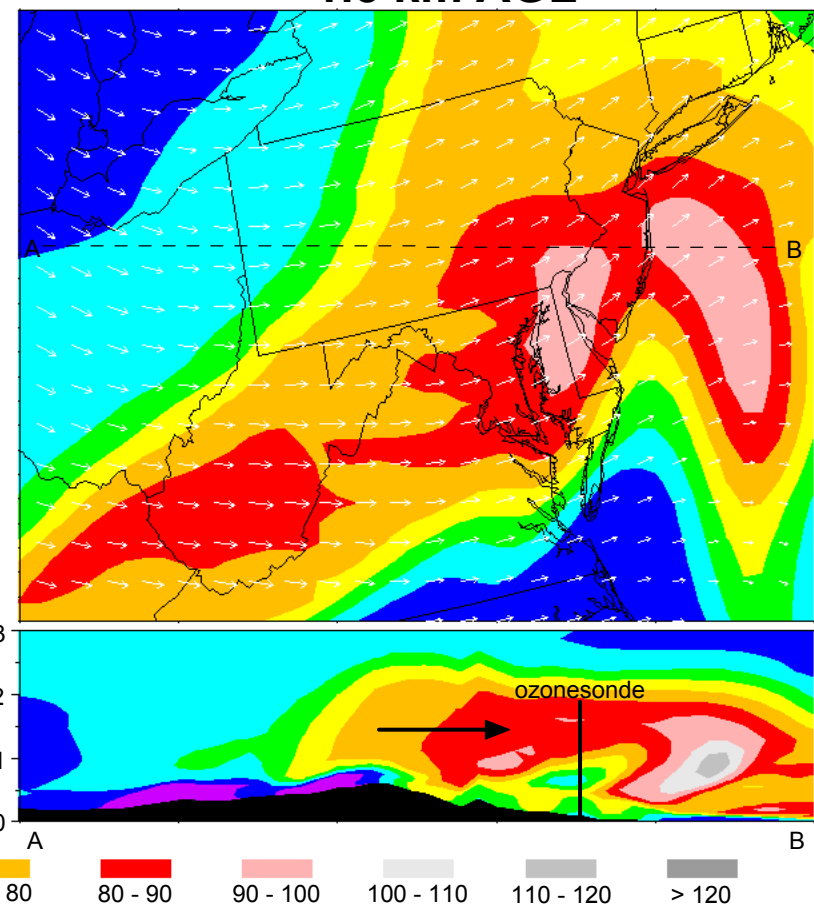**Observed and Simulated Ozone within 48 km of Philadelphia**

1-h max bias = -5.8   8-h max bias = -1.2   1-h min bias = 2.0

1-h max GE = 12.3   8-h max GE = 11.1   1-h min GE = 7.2
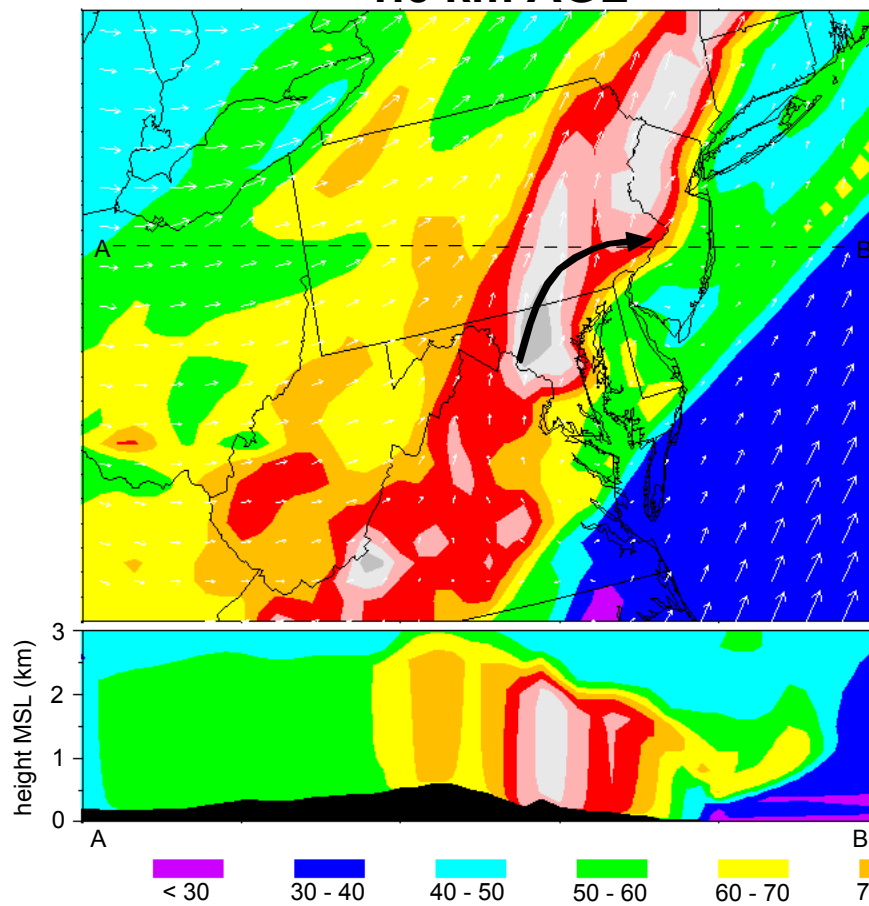
Regional Transport

17 EDT 10 August 1999
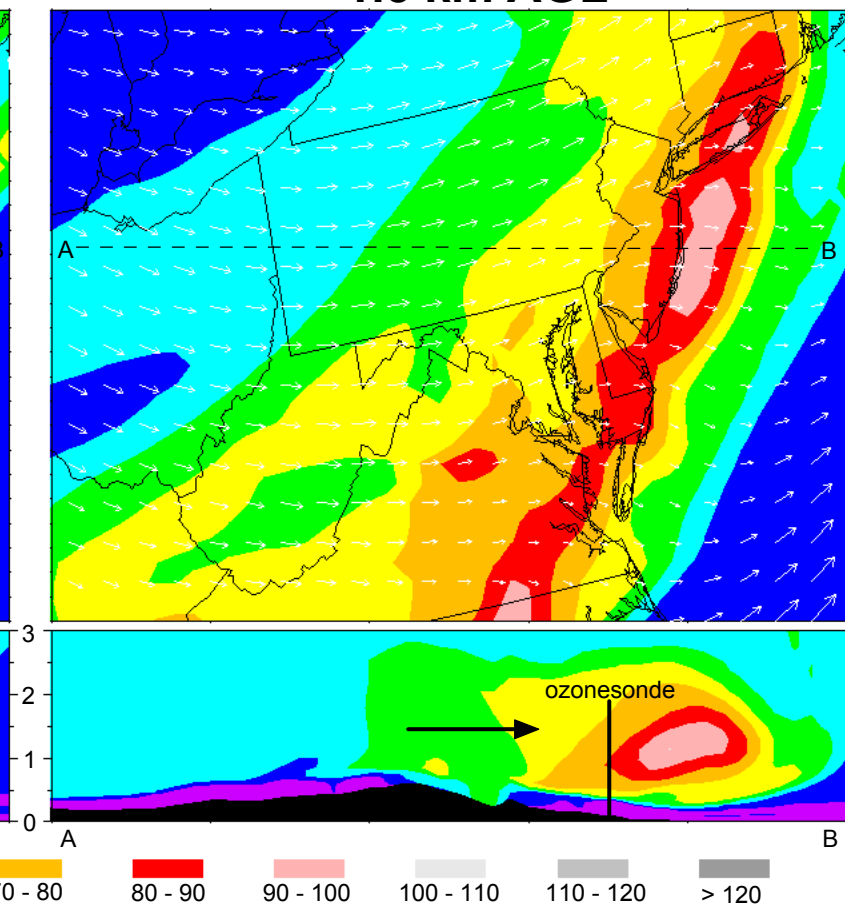**~ 1.5 km AGL**

08 EDT 11 August 1999
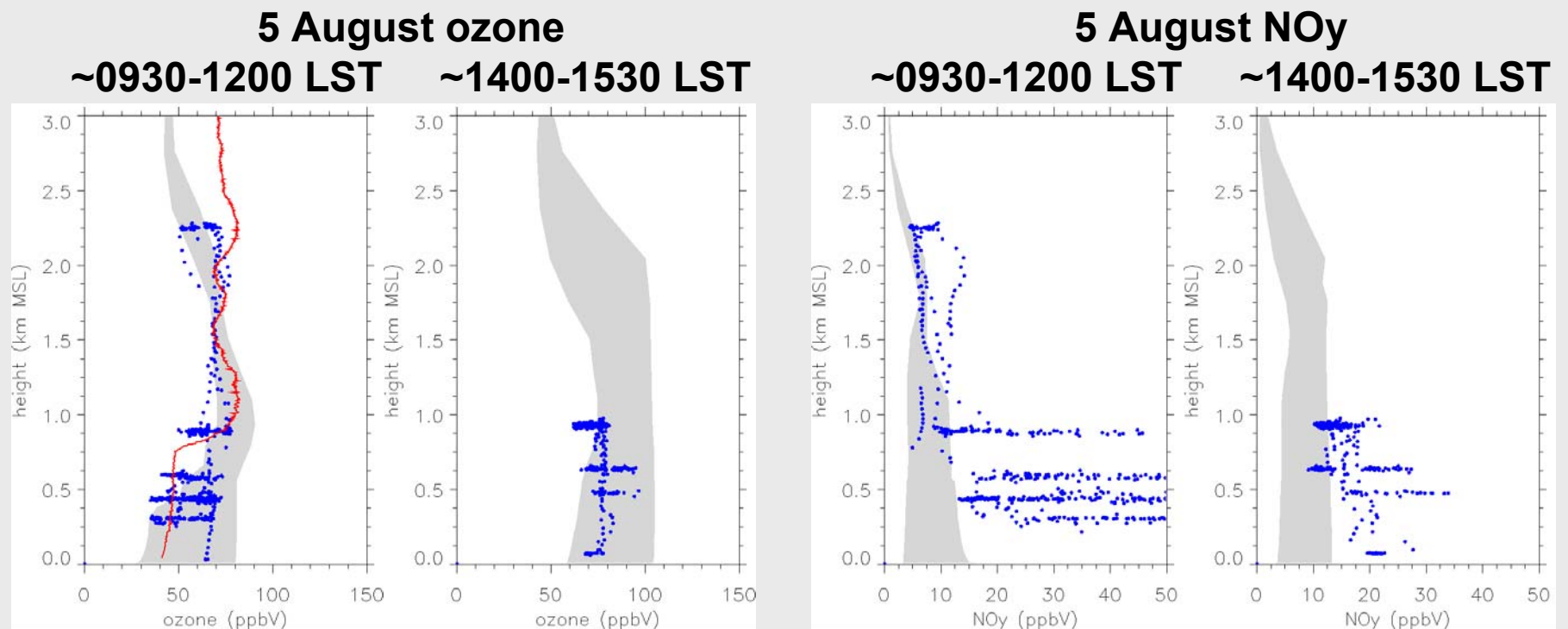**~ 1.5 km AGL**

height MSL (km)

ozonesonde

A   B   A   B

< 30   30 - 40   40 - 50   50 - 60   60 - 70   70 - 80   80 - 90   90 - 100   100 - 110   110 - 120   > 120

Regional Transport

17 EDT 4 August 1999
~ 1.5 km AGL

08 EDT 5 August 1999
~ 1.5 km AGL

ozonesonde

height MSL (km)

< 30   30 - 40   40 - 50   50 - 60   60 - 70   70 - 80   80 - 90   90 - 100   100 - 110   110 - 120   > 120

Ozone and NOy Aloft

5 August ozone
~0930-1200 LST   ~1400-1530 LST

5 August NOy
~0930-1200 LST   ~1400-1530 LST
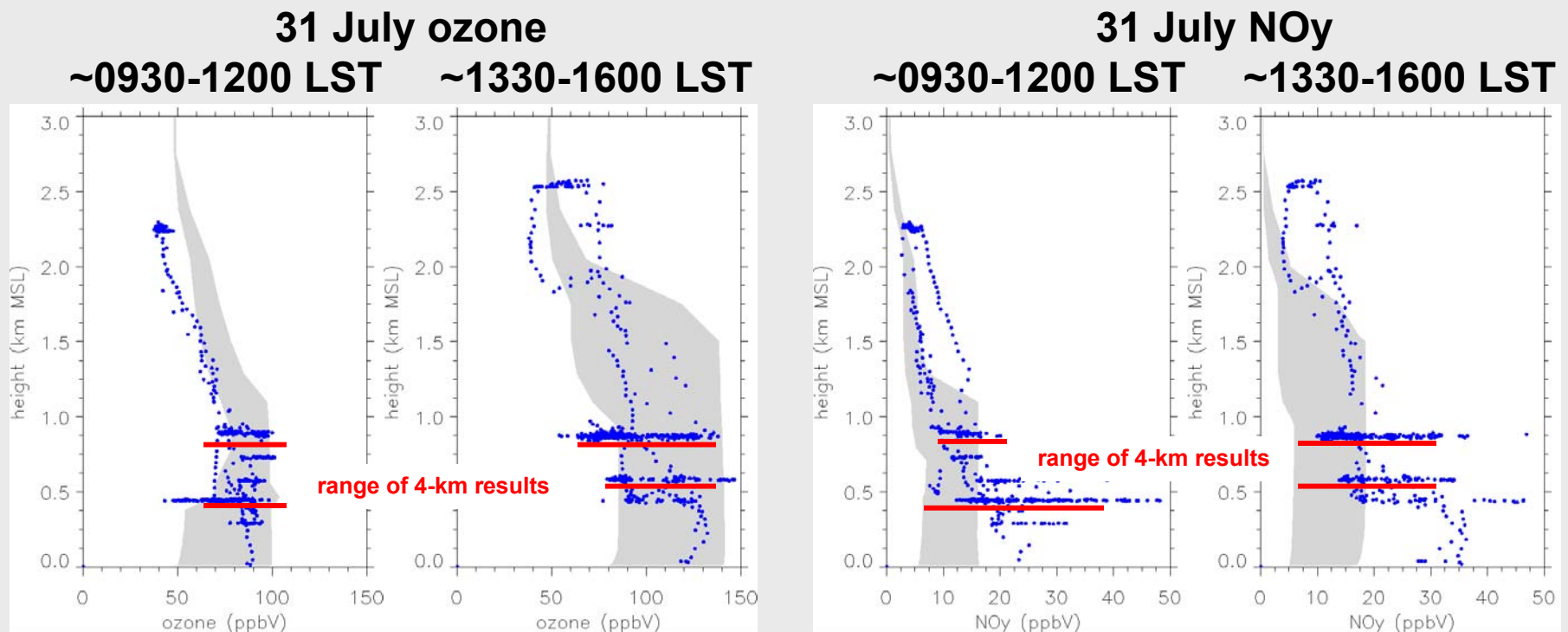

G-1   **ozonesonde**   **shaded: range of 24-km model results within a vertical column encompassing the G-1 flight path and during the flight period**
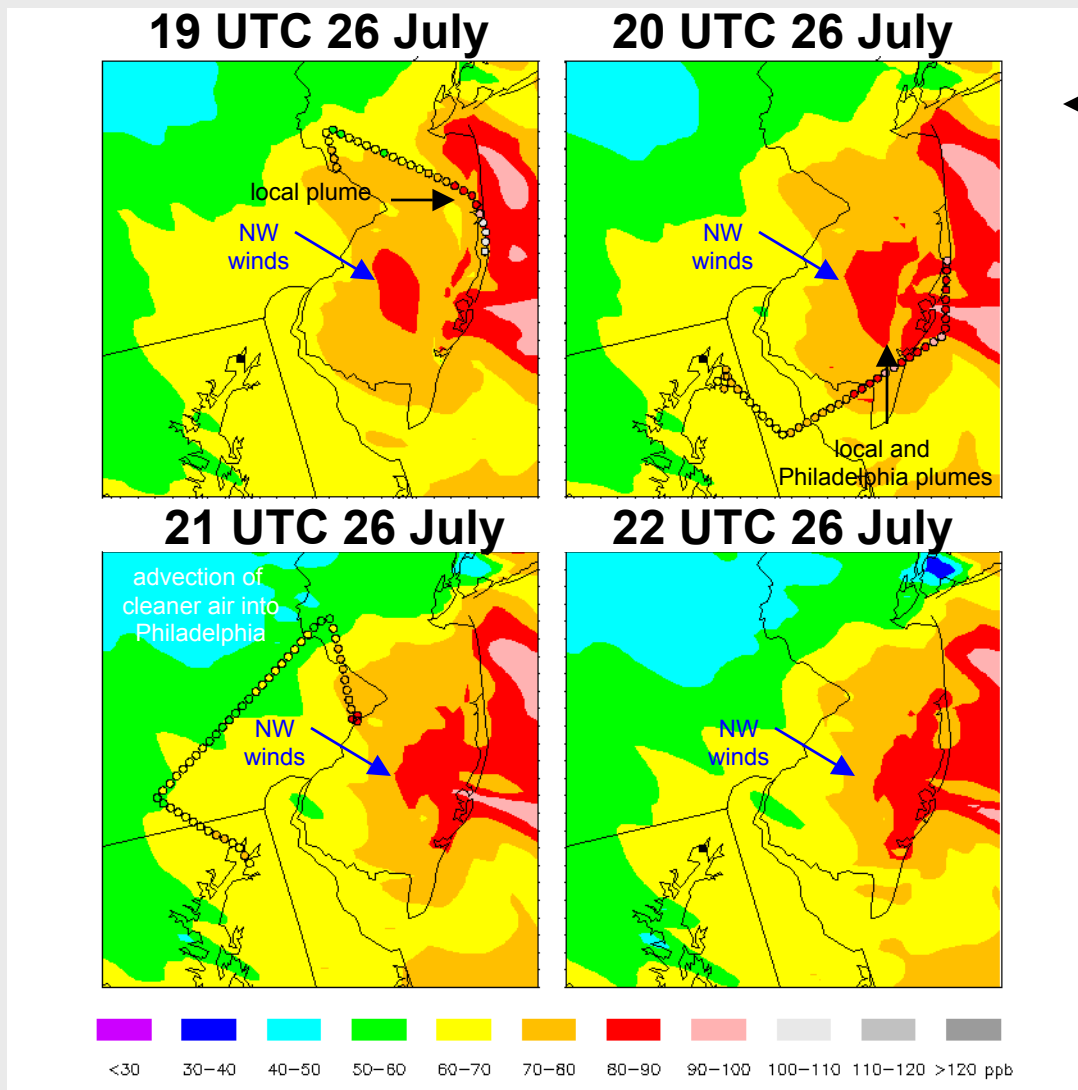
Ozone and NOy Aloft

31 July ozone
~0930-1200 LST   **~1330-1600 LST**

31 July NOy
~0930-1200 LST   **~1330-1600 LST**

➡ **24 km and 4 km ozone similar, but NOy better represented by 4 km**
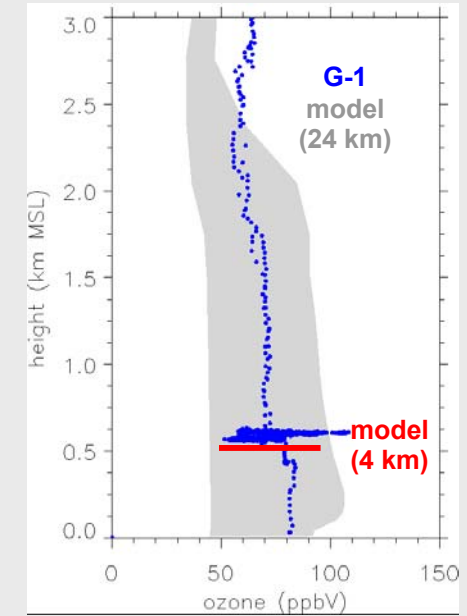
G-1   **shaded:**   **range of 24-km model results within a vertical column encompassing the G-1 flight path and during the flight period**
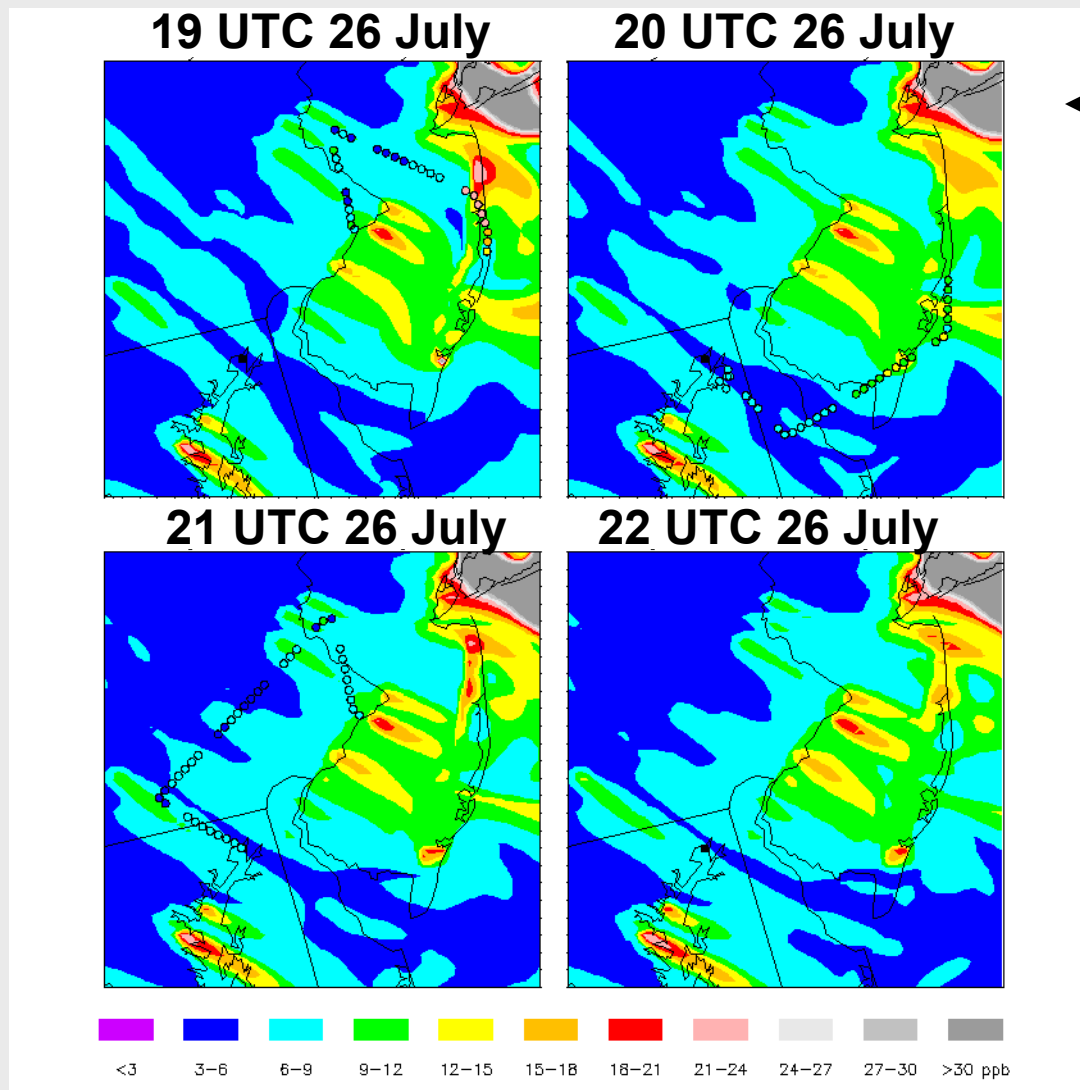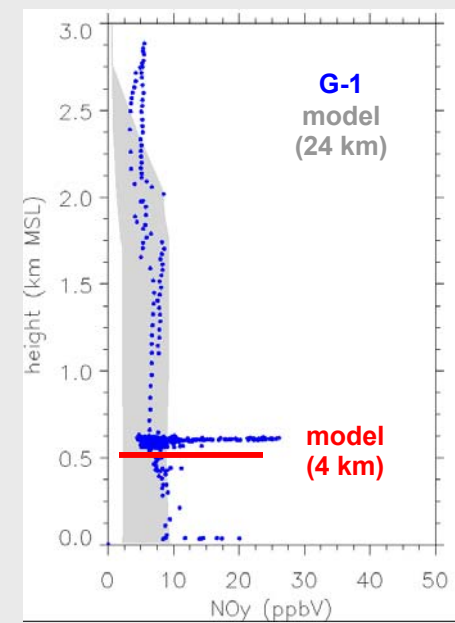
Local Transport: Ozone

Local Transport: NOy
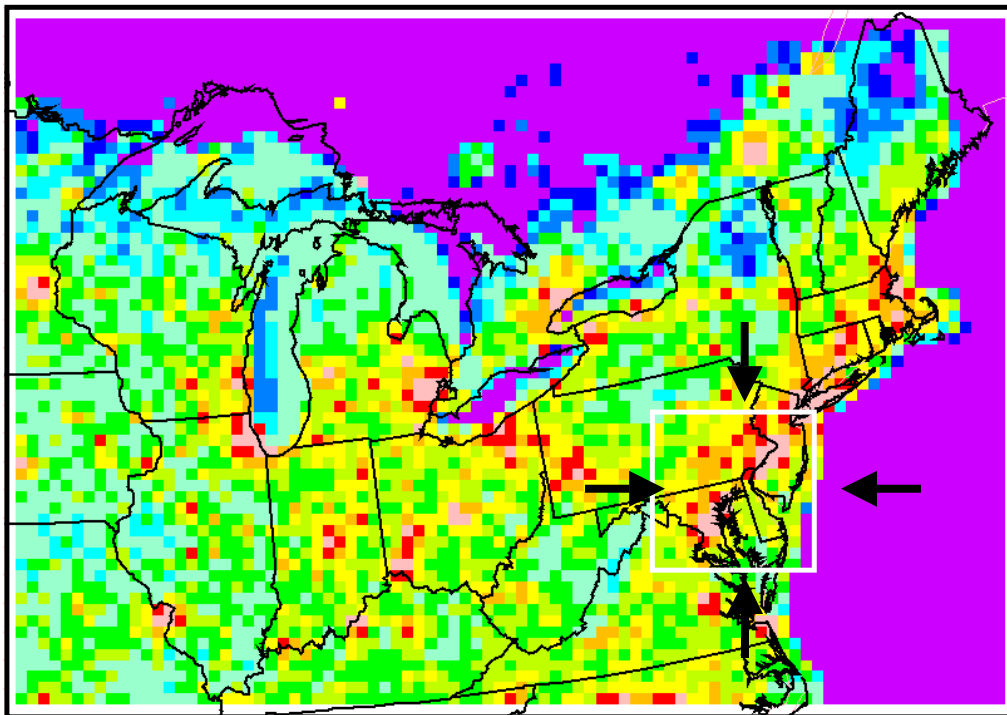

19 UTC 26 July

20 UTC 26 July

21 UTC 26 July

22 UTC 26 July

4-km simulation
~ 500 m AGL

<3   3-6   6-9   9-12   12-15   15-18   18-21   21-24   24-27   27-30   >30 ppb

Sensitivity Simulations

1) **local**
   only emissions within subdomain, background values imported into subdomain
2) **O$_3$ transport**
   same as 1), but include regional O$_3$
3) **O$_3$ precursor transport**
   same as 1), but include regional O$_3$ precursors

➡ **compare results with control simulation**

Daily Peak Ozone Mixing Ratios
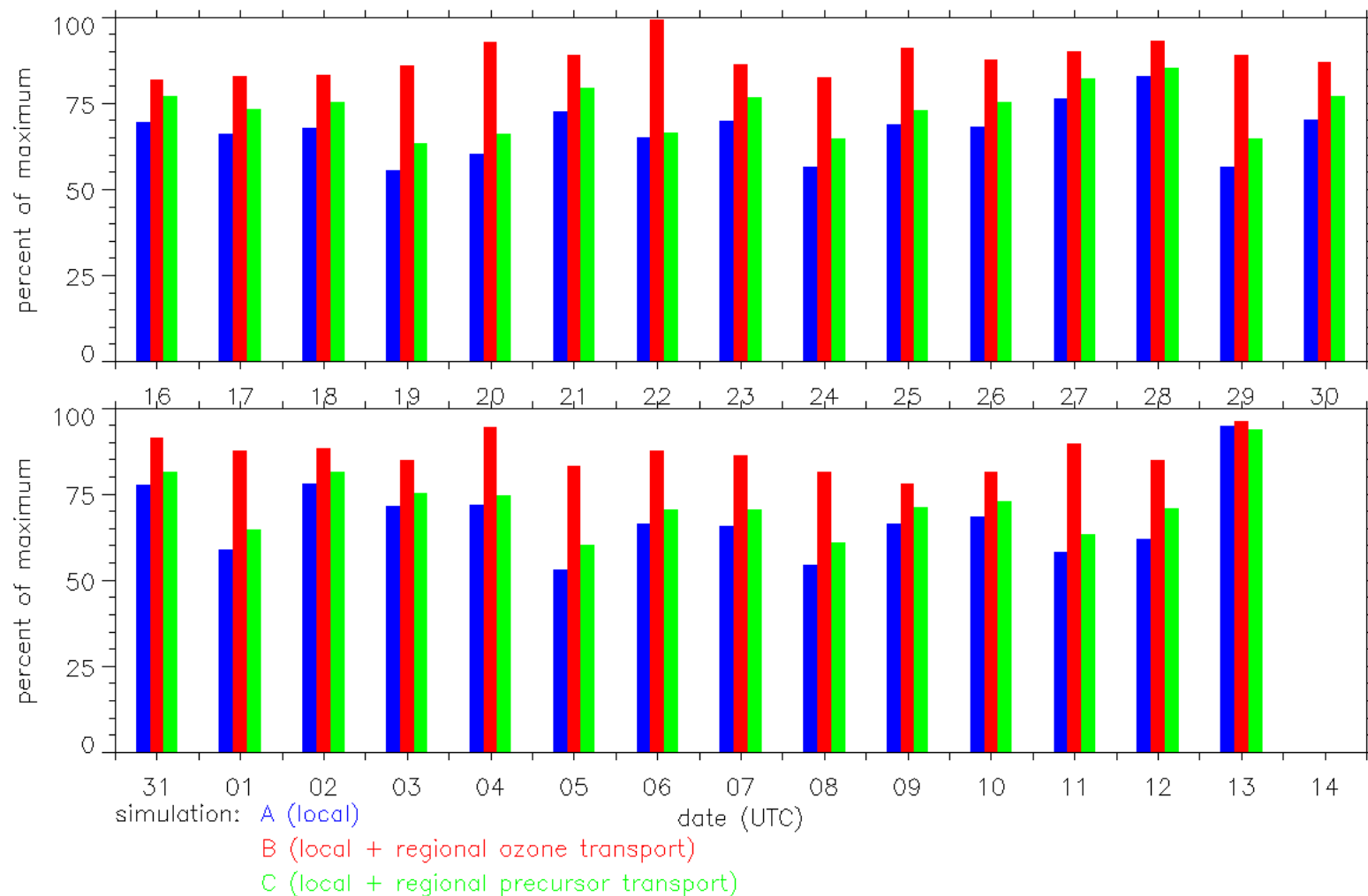
Summary

- **data showed concentrations of ozone significantly higher above the growing CBL on several mornings**

- **PEGASUS results compared very well with meteorological and chemical data at the surface and aloft**
  - O_3 **from the 24 km and 4 km simulations similar, but O_3 precursors better represented by 4 km simulation**
  - **near-surface vertical grid spacing critical to adequately simulate the nocturnal boundary layer**

- **sensitivity simulations showed that the majority of ozone was produced by emissions in Philadelphia and Chesapeake Bay area, but as much as 30-40% of the ozone could be attributed to transport from upwind sources**
  - **simulated regional pollutant plumes were not completely aged**
  - **several source regions usually contributed to the mix of pollutants**